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Impact of Environmental Factors on the Profit Efficiency of Rice Production: A Study in Vietnam's Red River Delta

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IMPACT OF ENVIRONMENTAL FACTORS ON THE PROFIT EFFICIENCY OF RICE PRODUCTION A STUDY IN VIETNAMS RED RIVER DELTA

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Long Van Hoang [α] & Prof. Mitsuyasu Yabe [σ]

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I. Introduction

Viet Nam is the second highest rice exporting country in the world. Rice production is important to the Vietnamese economy in general and to its agricultural sector in particular. It occupies a high share of the country's Gross Domestic Product (GDP), approximately 20.4% in 2006 (WB, 2008). However, as a result of rapid economic expansion and industrialization, land for rice production has become smaller and less fertile.

In addition, industrial development and the development of handicraft production are the major contributors causing lower water quality that impacts rice production.

The were some studies related to efficiency measurements of rice production such as technical efficiency [1, 2] and productivity [3]. However, the research related to profit efficiency is limited in the literature. This research aims to estimate the three dimensions of profitability of rice production, namely profit elasticity, profit loss and profit inefficiency. In addition, the environmental attributes affecting the profitability of rice production were determined.

Environmental degradation is a consequence of economic and industrial development in developing countries, especially Viet Nam. Water pollution has also been a major concern as pollutants from industrial production activities contaminate the rice fields and affect the country's overall rice production. Omission of variables presenting environmental factors do not only affect technical efficiency but also the profitability of rice [4]. Therefore, environmental factors such as soil quality, irrigation management, plant disease, and water pollution were given special attention in this study.

Farmers may combat environmentally constraining factors by allocating more labor and adding more chemical fertilizers to the input bundle of their production [5]. These activities may lower the productivity and increase inefficiency. As a result, advanced technologies like using machinery, new seeds, and fertilizers are major factors toward improving productivity.

The objectives of this research include the following. First, to determine the effects of the environmental factors on the profit efficiency of rice production. Second, to estimate the profit loss of rice production due to environmental factors. Third, to provide recommendations to policy-makers on how to sustain rice production. Finally, contribute to the literature pertaining to the methodological development of estimating the impacts of environmental factors on rice production.

This paper is organized as following. The next section will review the literature related to the estimation of efficiency giving special consideration to profit functions. The third section will describe the research areas and will explain the results of the household survey. The framework for analysis and the econometric specification will be presented in the fourth section. The fifth section will be the main section of the paper with the results and discussions from model estimation included. The sixth section will be the conclusions of the study and policy implications.

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II. Analytical Framework for Measuring Profit Efficiency

a) Analytical Framework

Economic efficiency is classified into two categories: technical efficiency and allocative efficiency [6]. The profit function combines both technical and allocative concepts in profit relationships, and any errors in production decisions are translated into lower revenue [7] , hence low profit efficiency .

Measuring efficiency was started by Farrell [6], who explained the ability to produce a given level of output its lowest cost. Ali & Flinn [8] estimated the profit efficiency by comparing the OLS (Ordinary Least Squared) and MLE (Maximum Likelihood Estimation) approaches to show the profitability of rice production in Pakistan. Rahman [9]estimated rice profit efficiency by using a translog function and added the farmer's characteristics to reasons for inefficiency. Kolawole [10] computed the profit function by adding a constant to profit function in to obtain the positive values while using the Cobb-Douglass function to estimate profit frontier.

The standard profit function assumes that markets for outputs and inputs are perfectly competitive.

$$\ln(\prod + \theta) = \ln f(P, W) + (V - U) \qquad (1)$$

wθ is a constant added to the profit of each firm in order to obtain positive values [10].

The farm profit is measured in term of Gross Margin (GM) which equals the difference between the total Total Revenue (TR) and Total Variable Cost (TVC)

$$GM(\Pi) = \Sigma(TR-TVC) = \Sigma(QP-WXi) \qquad (2)$$

The profit frontier approach is defined as:

$$\pi_i = f(P_i, Z_i).\exp(\xi_i) \qquad (3)$$

where π_i' is the normalized profit of farm *ith*; P_j' is the normalized input prices measured by dividing profit and input prices for output prices; Z_k is fixed inputs such as land and capital.

This function can be estimated by OLS of MLE [8]

The OLS approach of profit function is written as:

$$\ln \pi_i' = \alpha + \sum_i \alpha \ln P_i' + \alpha_L \ln Z_j' + \xi_i \qquad (4)$$

The translog profit function approach was used by Aigner et al. [11]; Meeusen & Broeck [12]; and Ali & Flinn [8]. The translog frontier form can be written as follows:

$$\ln \pi_i = \alpha + \sum_i \alpha \ln P_i' + \tfrac{1}{2}\alpha(\ln P)^2 + \alpha_L \ln Z + \tfrac{1}{2}\alpha(\ln Z)^2$$
$$+ \sum\sum \alpha \ln Z \ln P + \xi \qquad (5)$$

The paper used both forms of profit frontier to compare the coefficients between the different approaches of estimation.

Production inefficiency is measured by three components: technical, allocative, and scale inefficiency.

Error terms are

$$\xi_i = v_i - u_i \qquad (6)$$

Production/Profit efficiency of individual farm is defined as:

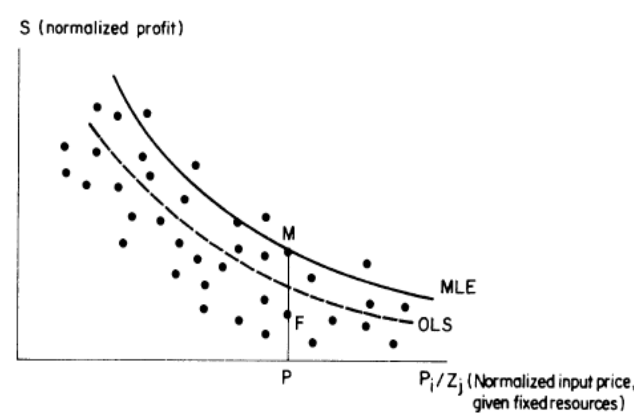
$$PE = E[\exp(-u_i) \mid \xi_i] = e[\exp(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}) \mid \xi_i] \qquad (7)$$

Precluding farm and household characteristics, other environmental factors/constraints are used to estimate efficiency including irrigation, land suitability, insects and pests, weed infestation, weather variation (drought and storm), and poor soil fertility [4]. In this study, four environmental factor variables were selected: irrigation, plant disease, soil fertility, and water quality.

b) Frontier MLE and OLS stochastic profit frontier

Fig. 1 shows the differences in estimation of profit efficiency by MLE and OLS approaches. The OLS estimate the average of profit value while the MLE estimate the profit frontier [8]. From the results of the MLE, the profit loss can be derived by dividing the profit of individual farms by profit efficiency.

Figure 1 : Relation between MLE and OLS in frontier estimation.



Source : Ali & Flinn [8].

III. Research Area, Data and Econometric Specification

a) Research Area and Data

The Red River Delta is of two rice granaries in Viet Nam. Although rice productivity has been gradually increasing in recent years due to the adoption of advanced technologies, the production is still challenged by constraints including land fragmentation, soil degradation, and water pollution. One of the reasons for this situation is the development of industrial production and handicraft production. Many industrial parks and production zones have been established near the rice fields, and the handicraft production villages are also increasing rapidly in quantity. Recently, the total number of craft villages has increased to 2790 craft-villages located throughout the country, half of which are located in the Red River region. This development makes the surrounding environment more polluted [13]. The problem of water pollution is at an alarming stage with about 90 percent of the craft-villages violating environmental standards.

Rice production in the Bac Ninh province still plays an important role in the economic development of the province (because of) with some special rice varieties that are well-known for their flavor. The province has the highest number of craft villages (n=61) in the country. The water pollution from these craft villages cause some many hectares of land in regions uncultivable and made farm households become having no land for cultivation.

This research was conducted in Bac Ninh province and one part of the capital in Ha Noi where rice production is still dominated by the local economy. In addition, these areas were selected to study the effects of water pollution on rice production in parallel with other environmental factors. Four communes were chosen for the survey, namely: Phong Khe, Da Ton, Phu Dong, and Ninh Hiep. The Phong Khe commune is located in Bac Ninh Province, while the three remaining communes were located near Ha Noi. The Phong Khe and Da Ton communes are located in polluted areas, while the remaining two communes are located in non-polluted areas. First, Phong Khe commune is located in Bac Ninh province, which is famous for its handicraft production. Paper recycling is one of the major local industries in this commune. This industry uses a large amount of "cleaning and colorful chemicals". A significant amount of wastewater is discharged directly into river without treatment. Therefore, almost all paddy rice areas are contaminated. Next, Da Ton commune is located near an industrial production zone named Sai Dong where pollutants from electronic companies are discharged to the nearby river that flows to the irrigation canals of the farmers. Thirdly, Phu Dong commune is located at the end of the downstream of a branch in the Red River. Water Pollution in this commune is relatively low. The source of the pollution in the water is mainly from household wastes, which do not affect rice production significantly. Finally, Ninh Hiep commune is less polluted because it is not near any production areas and the irrigation is used from a larger river, namely the Red River.

Surveys with rice farmers were conducted in four communes of two provinces in the Red River Delta namely Ha Noi capital and Bac Ninh province. A total 369 rice farmers were interviewed using a questionnaire. The survey was given during in the month of August 2010 by a group of enumerators after receiving brief training on the questionnaire. A pre-test was made to revise the questionnaire before the formal survey. Which in 369 rice farming households in the sample, 20 households were deleted from the sample due to minus values of profit in production. Finally, the sample used for profit function estimation is 349 households.

The dataset uses of variables including rice output (kg), rice yield (kg/sao), land (sao), the price of fertilizer ('000VND/kg) , pesticide ('000VND/100ml), labor wage (000VND/working day per man), land input (sao per farm), and capital ('000VND/farm). All value of these varialbes were converted to annual value instead of the value for each crop. Only 5 production inputs were used for the model estimation.

The environmental factors measured were soil quality, irrigation, disease, and water pollution. Managerial variables are age, gender, education, and family labor ratio. Futhermore, rice plot, monocropping, and adopting of row seeding technology are considered. Finally, access to loans from the banks was included.

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Table 1 : Description of Variables.

Descriptions	Measure	Mean	Standard Deviation	Minimum	Maximum
Output and inputs					
Rice output	kg per year per farm	1552.829	1198.26	90	10400
Rice Yield	kg per sao per annum	178.0096	44.49657	62.5	700
Fertilizer price	'000VND per kg	5.806547	1.895004	1.528205	20
Pesticide price	'000VND per 100ml	10.1832	9.296003	.9782609	75
Labor wage	'000VND per working day	73.2728	11.94356	33.36355	110
Land cultivated	Sao (1Sao=360m^2)	8.472063	5.445733	0.5	40
Capital (Rental cost for land preparation, harvesting, and transportation services)	'000VND per farm per annum	713.3011	584.7483	0	4484
Environmental factors:					
Soil quality	Dummy (1= good; 0= bad)	0.5799458	0.4942374	0	1
Irrigation	Dummy (0= N; 1= Y)	0.9539295	0.2099224	0	1
Diseases	Dummy (0= N; 1= Y)	0.9945799	0.0735209	0	1
Water Pollution	Dummy (0= N; 1= Y)	0.5338753	0.4995285	0	1
Managerial variables					
Age	Years	48.12466	9.70016	26	75
Male household head	Dummy (1= Male; 0=otherwise)	0.495935	0.5006623	0	1
HH size	Number of HH members	4.791328	1.51526	2	10
Education	Completed years of schooling	6.336043	3.110436	0	12
Experience in rice farming	Years of rice growing	27.7561	12.00544	0	57
Family Labor Ratio	Rate of No. of Family Labor and HH Size	0.3946369	0.2967001	0	1
Rice plots	Number of plots of rice fields that HH cultivate	4.01626	2.317175	1	17
Mono-cropping	Dummy (0= N; 1= Y)	0.0813008	0.2736676	0	1
Row-Seeding	Dummy(1=Row-seeding; 0=Broadcasting and others)	0.1544715	0.3618909	0	1
Credit	Dummy (1=borrow loan for rice production; 0=not borrow)	0.0189702	0.1366049	0	1
Total number of observations		349			

1USD equivalent to 20,000 VND in 2010.

b) Econometric Specification

To estimate the impacts of environmental factors on profit efficiency, first the stochastic profit function must be defined as:

$$\pi_i = f(P_i, Z_i).\exp(\zeta_i) \tag{8}$$

where π is normalized profit of the i *th* farmer is defined as gross revenue less variable cost, divided by farm output price; P is the vector of variable input prices faced by the ith farmer divided by output price; Z is the vector of the fixed factor of ith farmer. ζ_i is an error term; and I = 1,…,n is the number of farms in the sample.

The model was fist development by [14] and applied by [9] and [15].

$$\ln\pi' = \alpha_0 + \sum_{j=1}\ln P_j' + \tfrac{1}{2}\sum_{j=1}\sum_{k=1}\tau_{jk}\ln P_j' \ln_k' + \sum_{j=1}\sum_{k=1}\phi_{jl}\ln P_j' \ln Z_l$$
$$+\sum_{l=1}^{2}\beta_l \ln Z_l + \tfrac{1}{2}\sum_{l=1}^{2}\sum_{t=1}^{2}\varphi_{lt}\ln Z_l \ln Z_t + v - u \tag{9}$$

where Ps, Pf, Po, Pp, Ph, Pw, Zli, Zti are price of seed, price of fertilizer, price of organic fertilizer, price of pesticide, price of herbicide, labor wage, land area, and capital of each farm, respectively.

$$u = \delta_0 + \sum_{d=1}^{n}\delta_d W_d + \omega \tag{10}$$

where W is the variable representing socio-economic characteristics and environmental factors of the farm to explain inefficiency: (1) Age of household head; (2) Male household head; (3) Education (number of completed years of schooling); (4) Household size; (5) Family labor ratio; (6) Rice plots (the number of plots that households use to cultivate rice); (7) Mono-cropping (Dummy for household is to cultivate one crop per year; (8) Row seeding technique; (9) Household who take loans for rice production; (10) Dummy for soil quality; (11) Dummy for diseases; (12) Dummy for irrigation use (13) Dummy for water pollution.

IV. Results and Dicussions

a) Profit efficiency

Comparing the result of OLS and MLE demonstrates the small change in coefficients when using different methods to estimate profit frontier. In addition, the OLS estimation results shows that 69% of the dependent variable (profit) can be explained by the independent variable (production input). This indicates that production profit is close to the profit frontier.

Fertilizer price show a positive effect on profit. The reason is that the chemical fertilizers are mixed. Therefore the price is estimated by the average price of all fertilizers per kg. This shows that a higher price of fertilizer means that farmers use higher qualities of fertilizer. Therefore, it is rational to obtain a higher profit. The land area is positively related to the profit. This means that the margin profits increase when the area of land cultivated is increased. Also, this indicates economics of scale in rice production.

Land area dominates the profit share (share of profit?). Increasing the land area by 1%,will increase the profit by 1.2%. If the price of rice increases 1%, the profit will increase 0.7%. If the price of fertilizer increases 1%, the profit will increase 0.07%. If the price of pesticide increases 1%, the profit will decrease 0.08%. If the labor wage increases 1%, the profit will increase 0.9%. If capital increases 1%, the profit will decrease 0.09%. In this study, the increase in the price of fertilizer means that the farmers will use higher qualities of fertilizer and yield will be indirectly increased. An increase in cost of labor would mean the farmers use more hired labor than home labor which would increase the yield. The capital lowers the profit because capital is consider as input and it is better if farmers can rent capital.

Table 2 : Model Estimation for Profit Function.

Variables		OLS Estimation		MLE (Frontier Estimation)	
	Parameters	Coefficients	*t*-ratio	Coefficients	z-value
Profit function					
Constant	α_0	6.029***	6.85	6.324***	8.14
$\ln P'_F$	α_1	0.228	0.28	0.784	1.1
$\ln P'_P$	α_2	0.163	0.38	0.344	0.9
$\ln P'_W$	α_3	-0.615	-1.14	-0.509	-1.09
½ $\ln P'_F \times \ln P'_F$	α_4	-0.475**	-2.44	-0.451***	-2.88
½ $\ln P'_P \times \ln P'_P$	α_5	-0.042	-0.7	-0.064	-1.19
½ $\ln P'_W \times \ln P'_W$	α_6	0.523**	2.28	0.466***	2.44
$\ln P'_F \times \ln P'_P$	α_7	-0.114	-1.23	-0.025	-0.31
$\ln P'_F \times \ln P'_W$	α_8	0.244	0.96	0.210	0.99
$\ln P'_P \times \ln P'_W$	α_9	-0.019	-0.12	-0.031	-0.24
$\ln C$	α_{10}	0.138	0.63	0.045	0.24
½ $\ln C \times \ln C$	α_{11}	-0.028*	-1.61	-0.003	-0.18
$\ln P'_F \times \ln C$	α_{12}	-0.128	-1.1	-0.236**	-2.3
$\ln P'_P \times \ln C$	α_{13}	-0.024	-0.44	-0.0349	-1.14
$\ln P'_W \times \ln C$	α_{14}	-0.028	-0.35	-0.027	-0.39
$\ln P'_F \times \ln L$	α_{15}	0.037	0.27	0.115	0.98
$\ln P'_P \times \ln L$	α_{16}	0.005	0.08	0.0511	0.53
$\ln P'_W \times \ln L$	α_{17}	0.025	0.16	0.036	0.27
$\ln L$	α_{18}	0.013**	0.03	-0.010	-0.03
½ $\ln L \times \ln L$	α_{19}	0.353***	7.34	0.341***	7.58
R-squared		0.690			
No. of Observations		349		349	
Variance para. $\ln \sigma v^2$				-4	-12.66
$\ln \sigma u^2$				-1.85	-12.42
$\sigma^2 = \sigma u^2 + \sigma v^2$	$\sigma 2$			0.170	
$\lambda = \sigma u / \sigma v$	λ			3.313	

**** significant at 1 percent level (p<0.01), ** significant at 5 percent level (p<0.05), * significant at 10 percent level (p<0.10).*

b) Profit Inefficiency and Profit-loss

Farm households can maximize profit efficiency by minimizing profit inefficiencies. The factors that contribute positively to inefficiencies are household size, land plots and water pollution. On the other hand, factors that contribute negatively to inefficiencies are male household head, plant diseases, and irrigation. The disease and irrigation variables are not well defined in the data. The reason is the percentage of sample that was attacked by disease is 95% and irrigation apply is 99% (Table 1) . The reason for including these variables is to give evidence that almost all the farmers had disease attacks and irrigation service use in rice production.

Age of household head increases profit inefficiency. A young farm household head can work more effectively than an older one.

Household size increases profit inefficiency because the households with more members cannot use the home labor as well households with fewer members. Large households are composed mainly of dependents such as elders and children. They do not contribute substantially to the labor force for farming activities.

Table 3 : Estimation for Profit Inefficiency.

Variables	Para.	Coefficients	Standard Errors	t-ratio
Constant	β_0	0.351***	0.1727	2.04
Age	β_1	0.001	0.0012	1.19
Male HH head	β_2	-0.061**	0.0231	-2.67
Education	β_3	-0.003	0.0038	-0.94
HH size	β_4	0.060**	0.0264	2.29
Family labor ratio	β_5	-0.042**	0.0240	-1.75
Rice plots	β_5	0.052**	0.0238	2.22
Mono-cropping	β_7	0.053	0.0457	1.16
Row-seeding technique	β_8	-0.060**	0.0348	-1.74
Credit	β_9	-0.071	0.0861	-0.83
Env. Factors				
Soil quality	δ_1	0.074	0.1468	0.51
Diseases	δ_2	-0.047**	0.0235	-2.01
Irrigation	δ_3	-0.139**	0.0577	-2.41
Water Pollution	δ_4	0.043**	0.0259	1.67
Total number of observations		349		

**** significant at 1 percent level (p<0.01), ** significant at 5 percent level (p<0.05), * significant at 10 percent level (p<0.10).*

With the family labor ratio varialbe. Households with more members of working age will decrease the profit efficiency because they use more of their home labor in rice production rather than rental labor force.

The fragmentation of land is measured by the quantity of farm plots. The higher number of land plots may increase the production cost of rice [16] or reduce the production profit as a result. This is a critical issue in the Northern region of Vietnam as discussed in the previously stated literature

[17]. In this study, the number of plots show an increase in profit inefficiency or decrease in the profit of rice production. This indicates that the number of plots can increase production cost for rice producer households.

Table 4 : Estimation of Profit Elasticities.

Prices and fixed inputs	Profit elasticity
Rice price	0.690
Fertilizer price	0.072
Pesticide price	-0.086
Labor wage	0.956
Land area	1.257
Capital	-0.090

Source : Authors' estimation.

Mono production in rice farming means that a farm household cultivates only one type of crop per year. This strongly increases profit inefficiency. The reason for this is that rice production is not profitable or that one can find other opportunities to earn income than producing rice.

Appling the Row-seeding technique in rice production can decrease cost and increase productivity of rice production. This is the technique that farm households in the Red River's Delta should use when not using machinery for seeding.

The household with crop diseases will have decreased profit efficiency. The diseases in rice production are common now in Viet Nam in general and in the Red River's Delta in particular. However, if farmers use enough pesticide and they can combat the diseases. Farmers are very familiar about these diseases and they can prepare well to stop them.

Water pollution is a serious problem currently in rice production. The sources of pollution are industries and handicraft production where they discharge their waste water without any treatments. In this study, the rice producers in polluted regions have less profits because they have to spend more on labor and other input costs to abate pollution from chemical fertilizers, organic fertilizers, pesticides, etc.

Table 5 : Profit-loss by the Key Constraints.

Farm-specific Characteristics	N	Actual profit per ha	Estimated Profit-loss per ha[a]	Profit efficiency
Profit-loss by household size				
Small household size	255	11198.2	2758.276	.7648362
Large household size	94	10191.03	3169.689	.7140469
t-ratio		1.4460*	-2.2949**	2.9908***
Profit-loss by family labor ratio				
Low family labor ratio	171	9470.631	2679.177	.7301912
High family labor ratio	178	12325.95	3051.527	.7712975
t-ratio		-4.7532***	-2.3412**	-2.7218***
Profit-loss by farm plots				
Some farm plots	212	10803.16	2562.956	.7655034
Many farm plots	137	11118.45	3342.805	.7289557
t-ratio		-0.4970	-4.9150***	2.3577**
Profit-loss by mono cropping				
Not Mono cropping	325	11218.7	2885.818	.7443083
Mono cropping	24	6975.811	2642.512	.6857239
t-ratio		3.5260***	0.7690	1.8026**
Profit-loss by row seeding technique				
Not use row seeding technique	292	10501.35	2927.031	.7396094
Use row seeding technique	57	13107.07	2572.244	.8103105
t-ratio		-3.1522***	1.6431*	-3.4848***
Environmental factor effects				
Farm has plant disease	2	10225.69	918.6785	.900259
Farm has no plant disease	347	10930.97	2880.328	.7502972
t-ratio		-0.1718	-1.8570**	1.4883*
Profit-loss by soil quality				
Not Soil fertility	140	9560.321	2778.726	.7229509
Soil fertility	209	11842.36	2929.615	.7700504
t-ratio		-3.6787***	-0.9241	-3.0663***
Profit-loss by irrigation				
Farm without irrigation	15	7009.819	3597.521	.6195658
Farm with irrigation	334	11102.84	2836.372	.7570664
t-ratio		-2.7066***	1.9369**	-3.7273***
Profit-loss by water pollution				
Farm without water pollution	170	12439.08	2959.261	.7763847
Farm with water pollution	179	9490.8	2783.446	.7271969
t-ratio		4.9179***	1.0986	3.2716***
All farms	349	10926.93	2869.086	.7511566

[a] Profit loss is computed from the maximum profit (for?) given prices and fixed factor endowments.

Maximum profit per hectare is computed by dividing the actual profit per hectare of individual farms by its efficiency score.

**Significant at 10% (p<0.10); **Significant at 5% (p<0.05); ***Significant at 1% (p<0.01).*

V. Conclusions and Policy Implications

The estimation results show similar coefficients between OLS and MLE approaches. The inclusion of environmental factors show significant effects on profit efficiency. In specific, the environment changes the profit efficiency of rice production. Farmers receive approximately $150 of profit per hectare if they can control the production constraints. Therefore, in order to maximize profit, rice farm households need to overcome the obstacles such as labor and household size. However, there are some issues related to policy that the government should be involved in to support the farmers so that they can maximize their profits. These include land consolidation to minimize the number of farm plots, increasing farm size, technology, and water quality control. Advanced technology such as row seed tools and machine should be applied and promoted in rice farming. These are the policies that the government should consider to help sustain rice production in the Red River Delta and for the entire country as well.

VI. Acknowledgments

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